Journal of Alasmarya University: Basic and Applied Sciences
Volume (6) Issue 1 (March 2021) P: 20-29
مجلة الجامعة الأسمرية: العلوم الأساسية والتطبيقية
المجلد (6) العدد 1 (مارس 2021) ص: 20-29

An in Vitro Comparison of The Shear Bond Strength of Human Teeth to Bovine Teeth in The Bonding Orthodontic Brackets

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Abstract

Purpose: This study aimed to evaluate bovine enamel as such an alternative. **Methodology:** Ten human premolars and ten bovine incisors were bonded with two types of brackets, metallic brackets and ceramic brackets, using two types of adhesives, a composite resin adhesive (Concise) and a glass ionomer cements (Fuji Ortho LC). All samples were bonded and subjected to 750 cycles of thermocycling between 4°C and 55ºC with a dwell time in each temperature of 10 seconds and a 9 seconds interval between the two containers. Shear bond strength was tested using an universal Instron testing machine operating at cross head speed 0.02"/minute. **Results:** For brackets bonded with Concise, mean shear bond strength of bovine enamel was significantly lower than human teeth. Metallic Brackets bonded to bovine enamel exhibited 45%less bond strength than human enamel and ceramic brackets showed 28%less bond strength. No significant difference was observed between mean shear bond strength of either metallic or ceramic brackets bonded to bovine and human enamel when the adhesive used was glass ionomer cement. **Conclusion:** Bovine teeth could be used as alternatives to extracted human teeth for orthodontic bracket bonding studies.

Keywords: Shear bond strength, bonding, bovine teeth.

1.INTRODUCTION

The introduction of the acid etch technique by Buonocore in 1955[1]and the subsequent development of the bis-GMA type adhesives by Bowen in 1962[2], paved the way for the development of the direct bonding of orthodontic brackets to enamel with its accompanying benefits of space preservation, hygiene, esthetics, and time saving. The technique unfortunately came with many drawbacks that remain unresolved todate. Thus studies involved in attempting to improve the procedure are very common in the orthodontic literature. Obviously, in such studies, there is a need to obtain extracted teeth to have brackets bonded to their enamel for in-vitro testing. Obtaining enoughnumber of extracted human teeth to conduct such work is a serious problem for many researchers. With the advances in modern dentistry, extraction as a treatment option has become limited to badly decayed, irrestorable teeth, which in turn are not adequate for such studies. An ideal choice of teeth would be the human maxillary central incisors with their flat bonding labial surface that is reproducible

ISSN: 2706-9524 (Print) ISSN: 2706-9532 (Online)

from tooth to tooth. Obviously the supply of such esthetically important teeth is virtually impossible. The only option available is premolars extracted for orthodontic purposes, which are usually in a good condition with intact enamel. One of the limitations of premolar teeth is their variably curved buccal surface, which adds the variable of different adhesive thickness with different curvatures. Such limited choice, makes bonding studies more difficult and time consuming. Limited availability is the least of concerns with bonding studies.

The need for an alternative to human teeth for bonding studies thus becomes essential. The use of bovine teeth in bonding studies started appearing in the literature[3-8]. Bovine enamel is similar to human enamel[9].Teeth of all mammals are histo-chemically and anatomically similar [10-11].However, differences do exist between the two enamels. Bovine enamel has larger crystal grains and more lattice defects due to its rapid growth [12].It is also reported that bovine enamel has lower critical surface tension as compared to human enamel[13].Few studies have evaluated bovine enamel as an alternative to human enamel for bonding studies [14].These reported slightly lower bond strength to bovine enamel, which has been attributed to the lower critical surface tension, Also found a significantly higher number of dentin tubules in bovine teeth compared to human teeth. However, the diameter of tubules was the same in both types of specimens [15]. Morphologically compared the superficial morphology of bovine and human sclerotic dentin. No significant difference was found in the number of open dentin tubules in either species [16].In contrast, compared the tubular dimensions and distribution of human and bovine dentin in superficial, middle and deep dentin regions. Found that the number of tubules per square millimeter, regardless of the region, Was significantly higher in human dentin than in bovine dentin [17]. And also in a new search found bovine and human enamel are similar in composition, structure and hardness. But bovine enamel has higher fracture toughness than human enamel [18]. Despite these differences it has been reported that bovine teeth could be used as an alternative to human enamel with no statistically significant difference between them yet bovine enamel produces lower bond strength [14,19].

The aim of this study was to compare the bond strength of human enamel to bovine enamel with the use of two common bracket materials, stainless steel and ceramic brackets. Also different bonding materials were evaluated, composite resin and glass ionomer cement. Both human and bovine enamel were examined using scanning Electron microscopy.

2. Materials and methods

2.1.Materials

The sample of this study consisted of ten human premolars (H group) and ten bovine incisors (B group). Each group was divided into two main subgroups each consisting of five teeth, metallic bracket group and ceramic bracket group. Five teeth of each subgroup were bonded with composite resin adhesive, while the other five teeth were bonded with hybrid glass ionomer cement, Table I & table II list adhesives and brackets used in this study respectively.

Adhesive	Chemical type	Manufacturer
Concise	Self-cured adhesive: Paste-Paste	3M Dental Products St. PaulMinn. USA.
Fuji Ortho LC	Light cured, resin reinforced glassionomer: Powder-Liquid.	GC Corp., Tokyo, Japan

Table I: Adhesives, chemical type, and manufacturer used in the study.

Brackets	Method of cement retention	Manufacturer
Metallic, foil mesh standardedgewise bracket	Mechanical	Rocky Mountain Orthodontics, Denver CO, USA
All ceramic bracket	Silanated	GAC, Central Islip, N.Y. USA.

Table II: Brackets, their method of retention, and manufacturer.

2.2.Methods

2.2.a.Bonding procedure:

Both bovine and human teeth were cleaned and stored in deionized water after extraction pending testing. All teeth had the roots cut off at cervical margin using a saw. Crowns of teeth were embedded in acrylic blocks with the labial surface of teeth was the only part of the crown exposed.(Fig. 1) Brackets were bonded to teeth according to manufacturer's instructions. Specimens were bench cured for five minutes and stored at 37°C for 60 minutes.

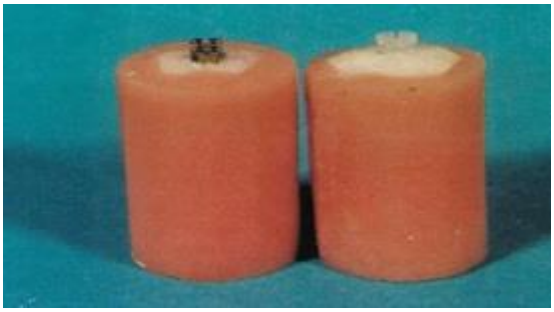

Fig. 1: Specimens mounted in acrylic cylinders

2.2.b. Thermocycling:

In an attempt to simulate oral environment, all specimens were subjected to 750 cycles between 4°C and 55°C with a dwell time in each temperature of 10 seconds and a 9 seconds interval between the two containers.

2.2.c. Testing:

Instron testing machine (Instron Corp., Canton, Massachusetts) was used to test failure load. Specimens were placed in a holder and a shearing blade moving with a cross head speed of 0.02”/minute was allowed to load the bracket-enamel interface and failure load of the bracket were recorded.(fig. 2).

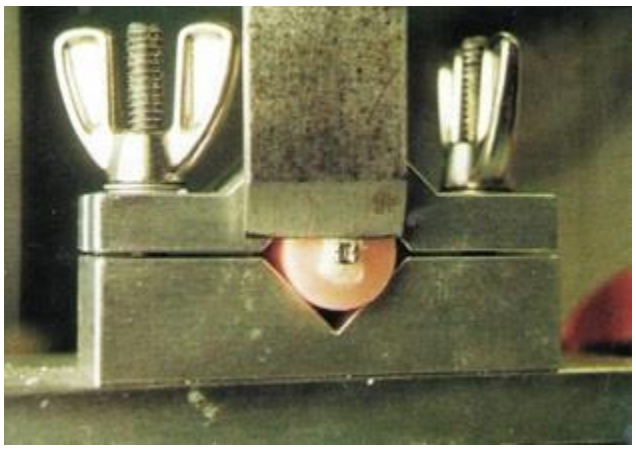

Fig. 2: Shear bond testing of brackets

2.2.d.Scanning electron microscopy:

After debonding samples were desiccated with a vacuum and sputter coated with gold palladium (Hummer VI, JOEL Techniques Ltd., Japan). Enamel surfaces of both human and bovine teeth were viewed with a scanning electron microscope (JSM 35, JEOL Ltd., Japan).

3. RESULTS

Mean values and standard deviations of bond strengths of metallic and ceramic brackets bonded with composite resin and glass ionomer cement to human and bovine enamel are listed in table III. Table IV describes the findings of the ANOVA test to test the significance of the difference between the bond strength to human and bovine enamel with the different bracket types and different adhesives. It was found that no significant difference existed between bond strength to human and bovine enamel for either metallic or ceramic brackets when Fuji was used to bond the brackets. When Concise was used to bond brackets, significant difference did exist between the mean shear bond strength to human and bovine enamel ($p<0.05$) for ceramic brackets and ($p<0.001$) for metallic brackets. Fig (3) shows the mean value for bond strength for all combinations of enamel type, bracket material, and adhesive used.

		Human		Bovine	
		Mean	**SD**	**Mean**	**SD**
Concise	Metallic bracket	21.05	**0.69**	**11.74**	**4.91**
	Ceramic bracket	14.83	5.3	10.56	4.39
Fuji	Metallic	6.35	2.4	7.83	0.67
	Ceramic	7.11	2.48	6.44	2.45

Table III: Mean bond strengths (MPa) and standard deviations of all samples of the study.

	Sum of Squares	**df**		**F**	**Sig**
Ceramic brackets / Fuji	Between groups	2.69	1	0.410	NS
	Within groups	150.98	23		
	Total	153.68	24		
Metallic brackets/ Fuji	Between groups	13.14	1	1.359	NS
	Within groups	222.35	23		
	Total	235.48	24		
Ceramic brackets / concise	Between groups	109.39	1	4.455	P<0.05
	Within groups	564.76	23		
	Total	674.15	24		
Metallic brackets/ concise	Between groups	520.27	1	19.860	P<0.001
	Within groups	602.53	23		
	Total	1122.806	24		

Table IV: Results of ANOVA of shear bond strengths of human and bovine enamel .

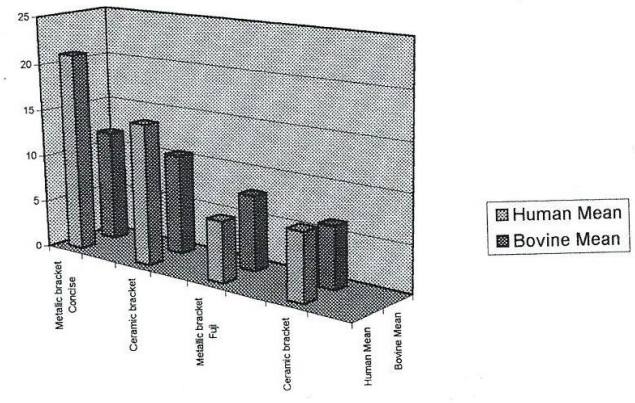

Fig. 3: Mean bond strength of ceramic and metallic brackets bonded with concise and Fuji to human and bovine enamel.

Fig. 4: Human enamel surface after etching with 37% phosphoric acid for 60s.

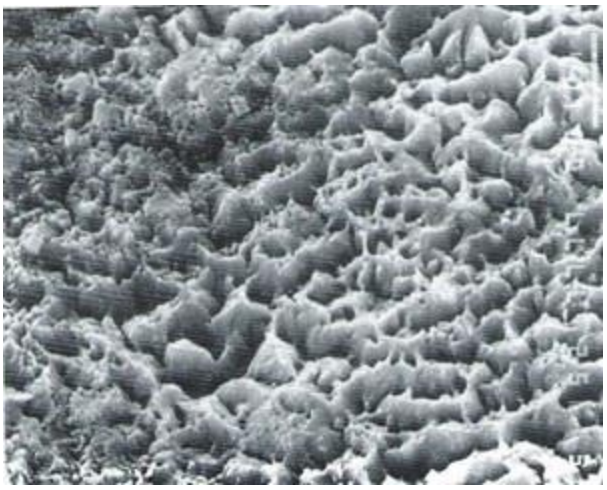

Fig. 5: Photomicrograph showing bovine enamel surface after etching with 37% phosphoric acid for 60s.

4.DISCUSSION

This study aimed to evaluate the validity of bovine enamel as an alternative for the use of humans teeth for bond strength study. Previous work by Nakamichi et al 1982 compared human and bovine enamel for bonding studies using two composite resins and three cements, glass ionomer, zinc polycarboxylate, and zinc phosphate[14].They tested bonding to both enamel and dentine and concluded that bovine teeth were suitable substitutes for human teeth in adhesion testing to both enamel and superficial dentine. Barkmeier and Erikson 1994 also studied bond strength to human and bovine teeth. Both those studies used adhesives designed for restorative dentistry. The findings of this study may be suitable for general bonding of restorations. In orthodontic bonding the adhesive is but one of many factors. There are different bracket materials as well as different retentive means in their bases. In this study both metallic brackets and ceramic brackets were tested. Also composite resin adhesive and glass ionomer cements, the two available adhesives for bonding brackets were tested. No significant difference existed between bond strength of both ceramic and metallic brackets bonded to human and bovine enamel with glass ionomer cements. Oestrele et al in 1998 evaluated deciduous and permanent bovine enamel as alternatives to human enamel for orthodontic bond strength studies.

For ceramic brackets bonded with composite resin adhesive, bond strength to human enamel was significantly higher than bovine teeth ($p<0.05$) while this significance level was more for metallic brackets ($p<0.001$). These findings are in agreement with Oesterle et al[9]who found that shear bond strength to bovine teeth was significantly lower than to human enamel. In their study they found that bond strength to bovine enamel was 21%-44% weaker than human enamel. They also found that bond strength to permanent bovine enamel was weaker than deciduous bovine enamel. In my findings with the use of composite resin adhesives with metallic brackets, as did Osterle et al [9]mean shear bond strength to bovine enamel was 45% less than human enamel. In my study, permanent bovine enamel was used. The result of this part of my study also compares favorably with the study by Barkmeier and Erickson [19].

In my study, two adhesives were evaluated. Composite resin adhesive and a glass ionomer cement. Both products tested, were marketed by their respective manufacturers as orthodontic bonding adhesives. As mentioned above, with the use of composite resin adhesive, bond strength to bovine enamel was significantly lower than to human enamel. However, with the use of glass ionomer cement there was no significant difference between bovine and human enamel with either ceramic or metallic brackets. The difference between the effect of the different adhesives on both bovine and human enamel tested could be explained by the different bonding techniques of the two adhesives. Composite resin adhesive bonding is based on etching enamel surface to create micro-pores through which unfilled resin flows, creating mechanical retention with the enamel. This is followed by placing the filled resin on the bracket base and on the tooth surface creating a mechanical lock with whatever mechanical mean of retention the bracket base offers from one side and a chemical bond with

the unfilled layer that is mechanically retained to the enamel. On the other hand, glass ionomer cement creates a direct chemical bond with enamel surface and thus no etching is needed. It seems that the multi-layered nature of the bond of composite resin and its dependence on enamel microstructure, makes the bond strength more variable. Bovine enamel develops more rapidly than human enamel and thus, has larger crystal grain and more lattice defects. It is also possible that a difference in the nature of calcification of human and bovine enamel due to diet and other factors would render the effect of acid etching on the superficial layer of enamel different. This was observed by the scanning electron microscopic examination of the surfaces of bovine and human enamel. Fig (4) and (5) show enamel surfaces of human and bovine teeth respectively after etching with 37% phosphoric acid for 60 seconds. It is obvious that they both exhibit successful etching, yet the pattern seems different. This may be a contributing factor in the difference in bond strength between human and bovine enamel when concise was the adhesive used. With Fuji Ortho LC, no etching was done during the bonding procedures and no significant difference did exist between the two types of enamel. It is thus evident that acid etching is the factor that does make a significant difference in bond strength of human and bovine enamel.

Another finding worth noting in this study is the difference in the level of significance between mean shear bond strength of ceramic and metallic brackets between bovine and human teeth. Bond strength of ceramic brackets to human enamel was significantly higher than bovine teeth ($p<0.05$) while the level of significance was ($p<0.01$) when metallic brackets were bonded. When metallic brackets were used bovine mean shear bond strength was 45% less than human enamel. When ceramic brackets were used, Mean shear bond strength to bovine enamel was 28% less than human enamel. This difference in the level of significance could be attributed to the different thermal conductivity of the two brackets tested. Obviously, metallic brackets are more heat conductive than ceramic brackets, thus thermocycling the samples affected the bond of the metallic brackets more than it did the ceramic brackets.

Lopez [20] reported a range of 3 MPa-5 MPa as adequate bond strengths for direct bonding of orthodontic brackets. If bovine enamel is to be used as substrates in studies of bond strength as an alternative to human extracted teeth, the values obtained should be adjusted to a higher value to simulate values that would have been obtained if human teeth were used. In other words, results of bond strengths with values slightly less that the minimum values would be considered clinically adequate if bovine enamel is used as a substrate in the laboratory study.

5.Conclusions

1. Bovine teeth could be used as alternatives to extracted human teeth for orthodontic bracket bonding studies.
2. In cases where bond strength study involves etching of enamel surfaces in the bonding procedure, results of bond strengths to bovine enamel should be adjusted to show higher values to simulate results that would have been obtained with human enamel.

3. In studies of bond strengths of brackets bonded without etching of enamel surfaces, results obtained from bond strength to bovine enamel probably correlate well to human enamel results and needs no adjustments. .
4. In cases were ceramic brackets are being tested to bovine enamel less adjustment to the results are needed as with studies of metallic brackets.

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مقارنة قوة الارتباط في المختبر بين أسنان الإنسان وأسنان الأبقار عند إلصاقها تقويم الأسنان بـ (BRACKET)

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الملخص

الهدف من دراستي هذه هو لتقييم طبقة آلمينا في أسنان الأبقار كبديل للأسنان البشرية ،عشرة أسنان بشرية قبل الطواحن وعشرة قواطع بقرية، ملصقة بنوعين من (brackets)، (bracket) معدنية و(bracket) الخزفية، باستخدام نوعين من المواد اللاصقة ،مادة لاصقة (Fuji Ortho LC) a ومادة لاصقة a composite resin (Concise) glass ionomer ،جميع العينات تم تلصقيها وتعريضها إلى 750 دورة من التدوير الحراري، علما بان درجات الحرارة تتراوح بين 4 درجات مئوية و55 درجة مئوية، مع بقائها الوقت المحدد في كل درجة حرارة تفصلها مدة 10 ثوانٍ ومدة 9 ثوانٍ بين الوعاءين، يتم اختبار قوة الارتباط باستخدام آلة اختبار عالمية Instron تعمل بسرعة 0.02 بوصة / دقيقة. تبين لي أنه في (bracket) التي ألصقتها بمادة composite resin، متوسط قوة الارتباط لأسنان الأبقار اقل بكثير من أسنان الإنسان ،وتبين أن قوة ارتباط (brackets) المعدنية الملتصقة بمينا الأبقار أقل بنسبة 45٪ من التصاقها بمينا الإنسان ، و عند استخدام (brackets) الخزفية تبين أن قوة الارتباط أقل بنسبة 28٪ ،ولم أجد فرق كبير بين متوسط قوة الارتباط لكلا من (brackets) المعدنية والخزفية عند إلصاقها لمينا الأبقار ومينا الإنسان بواسطة مادة glass ionomer.

الخلاصة: يمكن استخدام أسنان الأبقار كبدائل للأسنان البشرية لإجراء دراسات على قوة ارتباط (brackets) إلى الأسنان.

الكلمات المفتاحية : قوة الارتباط القصي ، الالتصاق، أسنان الأبقار.